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PATENT

Vibration Plate

[0001] The present invention relates to a vibration plate according to the preamble of Claim 1 having a baseplate which may be set into vibrations by an exciter device.
Typically, a baseplate of this type has a ground plate whose bottom vibrates flatly on the material to be compressed. Because of the high dynamic load, most baseplates are manufactured from massive thick steel plates, which are stabilized further via welded-on supports if necessary.

[0002] A soil compression plate, in which the baseplate is implemented as a ribbed hollow plastic part which is filled with sand or water before use, is known from DE 4307993 C2. This plastic baseplate to be ballasted is to produce less noise during soil compression and allow more favorable manufacturing. Specifically, the ribs extend from an upper cover plate to the ground plate and are particularly implemented as an open-cell honeycomb structure. The honeycomb structure is used in this case to elevate the mechanical strength of the plastic component, and the open-cell structure allows water or sand to be poured in and distributed to ballast the baseplate.

[0003] These known vibration plates have been used successfully in many applications for soil compression. However, it has been shown that if the typical plates are used, among other things, grain refining through grain fractures and abrasion occur when compressing uniform and closely graduated sands. It is disadvantageous in this case that grain refining as a result of the mechanical action during installation alters the soil-mechanical properties of the mixture, e.g., permeability, frost sensitivity, and compression features.

[0004] The quiet running of the known vibration plates is also problematic. Thus, in the event of increasing compression of the subsoil, irregular oscillations and tilting motions of the typical vibration plates may occur.

[0005] The present invention is therefore based on the object of providing a vibration plate having a baseplate which may be set into vibrations by an exciter device, during whose use strong grain refining no longer occurs and whose quiet running is simultaneously improved.

[0006] This object is achieved by a vibration plate according to Claim 1 and a baseplate according to Claim 22. Advantageous refinements are described in the subclaims.

[0007] The vibration plate according to the present invention has a baseplate, which may be set into vibration by an exciter device, having at least one ground plate, one top plate, and a cell structure positioned between the ground plate and top plate, which stiffens the baseplate, as supporting components, the supporting components forming a baseplate having a stiffness in which the lowest natural frequency of the baseplate is at least 2 to 5 times, preferably at least 3 to 4 times the frequency of its vibration.

[0008] In this novel vibration plate, the supporting components are thus connected to one another in such a way that they form a body having very specific vibration properties. The running properties of a vibration plate always improve significantly if the supporting components at least stiffen the ground plate in such a way that the lowest natural frequency of the baseplate lies in the above-mentioned ranges of the frequency of its vibrations during soil compression. In principle, a high stiffness at low weight generates high natural frequencies, the lowest natural frequency from the bandwidth of the natural frequencies of the ground plate to reach a minimum value here. Such a baseplate vibrates harmonically in the event of increasing compression of the subsoil before it passes over to irregular and undesired tumbling or tilting motions.

[0009] In contrast to DE '993, for this purpose the baseplate must be especially light precisely during the compression. For this purpose, supporting components known per se are used for stiffening and for lightweight construction in a way known from aircraft construction. An especially stiff and nonetheless light baseplate thus arises, which has the natural frequency values according to the present invention.

[0010] In particular, the cell structure is employed for the purpose of using a significantly thinner ground plate or top plate than previously. According to the present invention, this construction allows the use of 4 to 8 mm thick sheet steel plates, which results in a significant weight savings in relation to the known vibration plates made of steel.

[0011] The vibration plate according to the present invention therefore has a significantly lower vibrating mass. This has the advantage that the necessary amplitude for ensuring

sufficient compression may be generated using lower centrifugal forces. Therefore, lower unbalance masses may be used, which may in turn be driven using a lower power. The undesired grain refining may thus be reduced and the exciter device may simultaneously be operated more cost-effectively.

[0012] The significant weight reduction also allows the use of the vibration plate for compressing debris in general. In this context, debris is understood as a loose stratification structure, formed from more or less unequally large and loosely arrayed individual grains, having large pore spaces. Through compression, this loose stratification structure may be converted into a pore-filling graduated, dense stratification structure which is low in cavities. In this case, the grains may be sand or pebble grains or even snow and ice crystals, for example. The vibration plate according to the present invention may thus also be used in the care and preparation of ski pistes, cross-country skiing courses, or ski jumps to achieve longer service lives, without the plate sinking into the snow. This field of use is not accessible to the typical vibration plates because of the massive or ballasted implementation of the ground plates and the high weights resulting therefrom.

[0013] The vibration excitation of the baseplate is performed in this case with the aid of an exciter device. This may be a rotary exciter or directed oscillator mounted on or even in the baseplate, for example. In this context, excitation through an individual exciter or even through multiple hydraulically or mechanically synchronized exciters is also conceivable. Continuous shafts having one or more exciter weights are alternatively also usable as rotary exciters or directed oscillators. Eccentrically mounted shafts may also be used here.

[0014] In a preferred refinement of the present invention, the supporting components are welded to one another to form a self-supporting body. Through the welding of the ground plate to the cell structure and the top plate, an extraordinarily stiff body having further improved vibration properties arises, which may be handled easily even during production.

[0015] This light construction also allows a significantly wider execution of the plates running orthogonally to the operating direction. Thus, baseplates made of thin, high-strength steel having widths of approximately 2.25 m and a contact area of approximately 10,000 cm^2 may be executed, which result in a total weight of the vibration plate of below 400 kg. The corresponding surface pressure of such a vibration plate is then only 0.4 N/cm^2 instead of the

typical 5 N/cm^2. In principle, it is advantageous if the surface pressure of the vibration plate because of its intrinsic weight is between 0.1 N/cm^2 and 3 N/cm^2. In this case, the intrinsic weight of the vibration plate is to be understood as the total weight of the vibration plate when it is ready for use. This includes, among other things, the weight of the baseplate and the weight of the exciter device, including the weight of possibly existing drives and/or suspension devices of the vibration plate. In this case, the surface pressure as a result of intrinsic weight is the weight force resulting from the intrinsic weight which the vibration plate exerts on the flat soil surface it contacts.

[0016] According to the present invention, the vibration of the baseplate may be set as desired at a frequency between 30 Hz and 60 Hz. Thus, the frequency of 30 Hz may be adjusted up to larger frequency values continuously, in steps, or fixed in one step. This frequency adjustment is particularly necessary when compressing debris, sand being compressed at approximately 60 Hz.

[0017] In a further embodiment, the vibration of the baseplate may be set as desired at an amplitude of more than 0.1 mm and less than 10 mm, preferably 5 mm. The amplitude may also be set from a value of 0.1 mm up to larger amplitude values continuously, in steps, or fixed in one step.

[0018] In a refinement, the baseplate is reinforced in that it has at least one longitudinal girder welded to the cell structure as a further supporting component. This girder extends parallel and over a significant part of a long side of the baseplate. For this purpose, the long side of the baseplate is understood as the longest side of the baseplate. It is essential in this embodiment that the longitudinal girder decisively reinforces the baseplate in regard to its flexural and torsional strength. In addition, the cell structure welded thereto is also held better by the girder, which in turn further elevates the overall stiffness of the baseplate. Especially suitable girders are manufactured from closed annular or box-type hollow profiles.

[0019] It is expedient if the longitudinal girder is positioned below the exciter device. Thus, the baseplate is additionally stiffened particularly in the highly loaded region below the exciter device and the possibility is simultaneously provided of attaching the exciter device to the baseplate in a simple way, using screws, welding, or rivets, for example.

[0020] In order to further increase the overall stiffness of the vibration plate and particularly the baseplate, the longitudinal girder is implemented as a frame lying on the ground plate. A significantly increased spatial stiffness of the longitudinal girder itself thus results, which may be increased even further if the stiffening cell structure is welded into the intermediate space enclosed by the frame. In addition, as already described above, the cell structure is also welded around the frame. This embodiment of the support allows a relatively wide exciter device to be attached to the vibration plate.

[0021] In an especially preferred refinement, the individual cells of the cell structure each have a base whose maximum lateral extension is 20 mm to 200 mm, preferably 56 mm to 162 mm. This very fine-celled cell structure allows the ground plate in particular to be implemented as very thin, because of the narrow support interval of the cell walls, without strong buckling of this baseplate, which is only 4 mm to 8 mm thick, resulting.

[0022] The cell structure typically has at least partially closed cells having polygonal bases. The execution of the cell structure from partially closed cells results in further stiffening. The execution using different polygonal bases has the advantage that the cell structure may even be tailored to more complicated geometries of the outline of the ground plate. Triangular, rectangular, pentagonal, or hexagonal and polygonal regular or even irregular shapes are advantageous.

[0023] In a preferred embodiment, the cell structure has cells having at least partially round bases. It is thus possible to provide even rounded bases of the ground plate with a cell structure. It is also advantageous to manufacture the cell structure from tubes, individual tube sections simply being joined to one another. For this purpose, circular cylindrical tubes may be used, for example.

[0024] In an advantageous refinement, the cell structure at least partially has different cell shapes. This has the advantage that the stiffening effect of the cell structure may be varied distributed over the ground plate. This may be performed to adapt the stiffness to the load situation. Thus, a cell structure having especially many small cells would be used in regions having an especially large load, e.g., at the edge of the ground plate or in the region of the vibration excitation. More complicated geometries of the baseplate may also be manufactured

using different cell shapes. Thus, for example, the cell structure may be tailored to a drop-shaped cross-section of the baseplate.

[0025] The cell structure preferably has closed cell side walls. A high stiffness and strength of the cell structure in the particular cell wall planes thus results. This simultaneously allows continuous welding of the cell structure with adjoining supporting components such as the ground plate, the top plate, or the longitudinal girder. The weld seams are longer than in an open-cell construction, in which the cell walls have recesses in the wall base regions. This increases the strength and allows thinner cell walls to be used. At the same time, the walls of the longitudinal girder or the lateral plates of the baseplate, which terminate the cross-section, may also be used as cell walls.

[0026] In order to achieve good and uniform load dissipation and producibility of the cells, they are designed in such a way that planes of the cells parallel to the base each have the same shape and area as the base. In concrete form, this means that rectangular cells, for example, may have side walls positioned at an oblique angle to the base, for example, but diametrically opposing cell side walls run parallel to one another. The cells are preferably shaped so that the cell side walls are essentially loaded by perpendicular forces. For this purpose, the cell side walls are best positioned perpendicularly to the supporting ground plate and/or top plate and run linearly away therefrom.

[0027] It is not always necessary to support the top plate by the cell structure precisely like the ground plate, e.g., if the cell structure is only used to reinforce the ground plate in some regions. It is then advantageous not to lead the cell structure from the ground plate up to the top plate and thus achieve a further weight reduction. In such a case, the cell structure is expediently open on top.

[0028] The cell structure is preferably partially closed on top by the top plate. This only partial covering typically occurs if other components of the vibration plate cover the cell structure on top. In any case, however, the cell structure is to be protected by other covers from penetration of material to be compressed, if necessary.

[0029] Independently of this, if the top plate is solidly connected to the cell structure, it results in further stiffening of the baseplate. The cell structure is also covered on top so that

no material to be compressed may collect in the cell structure. The weight of the vibration plate and/or the baseplate thus remains constant even in the event of long use. Weight changes due to accumulations of the material to be compressed thus may not lead to a change of the vibration properties of the vibration plate. Furthermore, the top plate makes cleaning of the vibration plate easier. A removable top plate is also advantageous.

[0030] In another refinement, the bottom of the ground plate is at least partially provided with a wear protector. This has the advantage that the ground plate, which is implemented as very thin because of the desired weight reduction, is not worn or damaged due to friction with the material to be compressed. Such a wear protector may be a coating made of a suitable plastic which is glued onto the ground plate or even a plastic or metal plate clamped onto the ground plate, which is easy to replace. The wear protector may be attached to the baseplate through screws, rivets, or clamps, for example.

[0031] In a further embodiment, profiled strips are attached externally to the ground plate. This leads to further stiffening of the baseplate and, in addition, to profiling of the subsoil. For this purpose, different profiles, such as trapezoids, triangles, or even wavy profiles, are usable. They may also be attached to the ground plate through screws, rivets, clamps, or gluing, for example.

[0032] In principle, the vibration plate may be self-driven and provided with a handle so that it may be pushed or pulled vibrating over the soil by a person in a generally known way. One then refers to a self-driven vibration plate. In an advantageous embodiment, however, the vibration plate has a vibration-insulated suspension for installation on a self-propelled support device, which is connected to one of the supporting components of the baseplate. It is then a non-self-propelled vibration plate. The suspension is best connected to the longitudinal girder or via the cell structure to the baseplate. Through the direct connection to the cell structure, it is possible to dispense with a further fastener. The vibration insulation of the suspension may be produced in this case, for example, via rubber or even spring-damper elements and results in the vibrations of the vibration plate not being transmitted to the self-propelled support device. Such a self-propelled support device may be a tractor, a snowcat, a street construction vehicle, or even a rolling mill drive for soil processing, for example.

[0033] In a further embodiment of the present invention, the exciter device is attached to at least one of the supporting components of the baseplate. Typically and especially expediently, the exciter device is attached to the longitudinal girder, as described above. However, embodiments in which the exciter device is attached directly to a possibly specially reinforced cell structure are also expedient.

[0034] Normally, a separate drive is provided for the exciter device, e.g., a gasoline engine on the vibration plate. In the event of an especially light vibration plate, however, a drive of the exciter device positioned on the vibration plate is dispensed with. Instead of this, the exciter device may be coupled to a drive of the self-propelled support device and driven thereby. The exciter device is then driven in a typical way by a hydraulic or even mechanical drive. For this purpose, the exciter device has couplings for hydraulic lines or a driveshaft, for example, which may be connected to the corresponding counter couplings of the self-propelled support device.

[0035] It is especially advantageous if the baseplate has an operating width essentially corresponding to its long side, which is at least approximately as wide as the self-propelled support device. In particular, the operating width is to be wider than the lane of the support device. The vibration plate thus smoothes the lanes left behind by the support device when the vibration plate is pulled behind the self-propelled support device. For this purpose, the vibration plate is aligned with its long side perpendicular to the travel direction. Along the operating width, the vibration plate has a compressing effect on the material lying underneath it. Because of the especially wide embodiment, an especially effective mode of operation of the vibration plate results.

[0036] A vibration plate whose baseplate has a cross-section in which the region of the ground plate lying forward in the operating direction is curved upward together with a forward region of the top plate is especially well suitable for debris compression. The upward bend of the ground plate lying forward in the operating direction prevents the plate from digging into the material to be compressed. Because the top plate is also bent upward, a cell structure may be positioned between the two plates. This provides the two very thin plates, which are bent upward, with good spatial stability.

[0037] So that parts of the material to be compressed possibly arriving on the vibration plate do not collect there, the baseplate (2) preferably has a cross-section in which the region of the top plate lying to the rear in the operating direction is slanted falling downward toward the ground plate. Thus, for example, snow or sand residues simply slide off from the surface of the baseplate to the rear.

[0038] In the following, the present invention will be explained further on the basis of an exemplary embodiment illustrated in the drawing.

[0039]	Figure 1	schematically shows the section A-A through a vibration plate reinforced with a cell structure;
[0040]	Figure 2	schematically shows the top view of a part of the vibration plate shown in Figure 1 with the internal cell structure illustrated;
[0041]	Figure 3	schematically shows the detail illustration of the section B-B of the vibration plate shown in Figure 1 and Figure 2;
[0042]	Figure 4	shows a cell structure having a rectangular base; and
[0043]	Figure 5	shows a cell structure having a triangular base.

[0044] In detail, Figure 1 shows the section A-A through vibration plate 1 for compressing and smoothing ski pistes. It contains a baseplate 2, which is stiffened using a cell structure 5, an exciter device 9 for generating vibrations, and a device support 10, which is attached to a self-propelled support device.

[0045] In the embodiment shown here, the baseplate 2 contains a ground plate 3, a top plate 4, an interposed cell structure 5, and a longitudinal girder 8, which are all made of steel, as supporting components. The exciter device 9 is attached to the frame-shaped longitudinal girder 8, which is in turn welded to the ground plate 3. The longitudinal girder 8 runs over the entire long side of the baseplate 2 in this case.

[0046] In this embodiment, the cell structure 5 comprises continuous and vertically running cell long walls 6 and cell transverse walls 7, positioned perpendicularly to one another, which are welded permanently to the baseplate 2 and the top plate 4 here. The cell walls have a wall

interval from 50 mm to 150 mm in this case and have no openings. Therefore, this is a closed-cell cell structure having hollow cells which are cuboid in the central region of the baseplate. In the region enclosed by the frame-shaped longitudinal girder 8 and along the side plates 14, the cell walls 6, 7 are positioned more closely, since this region is loaded especially strongly by the exciter wave device. The cell structure 5 welded to the girder 8 simultaneously stabilizes the girder 8, and thus forms, together with the ground and top plates which are also welded on, a light, self-supporting body having high torsional and flexural strength.

[0047] In this embodiment, the baseplate 2 is curved upward on the side lying forward in the operating direction, in order to push snow which collects in front of the vibration plate under the vibration plate and slide well over wavy ground. In order to support the 4 mm thick top plate and equally thick ground plate, both plates are curved upward and the interior lying between them is reinforced using the cell structure 5 made of 3 mm thick sheet steel. The ground plate 3 and the top plate 4 run toward one another to a point, a crimp 15 of the ground plate 3 forming the tip of the baseplate 2 and simultaneously a support for the top plate 4. In the rear region of the baseplate, the top plate 4 drops toward the ground plate 3, a very narrow crimp 16 of the ground plate 3 forming a rear support for the top plate 4.

[0048] The ground plate 3 is provided on the bottom with a wear protector 12 made of abrasion-resistant plastic. This is screwed onto the ground plate 3 and prevents damage to the ground plate 3 from sharp stones which project out of the snow, for example. On the rear end of the ground plate 3, a profiled strip 13, which is mounted transversely to the travel direction over the entire width, is located below the ground plate 3. This strip is also attached replaceably and is used for further stiffening of the end section of the baseplate 2 and also for profiling the compressed snow and stabilizing the position of the vibration plate as it slides over the snow.

[0049] The vibration plate 1 is suspended on a self-propelled support device which travels in front, such as a snowcat in this case, and is pulled over the snow by this device. The device support 10 of the snowcat is used for suspension. This is attached to the vibration-insulated suspension 11 of the vibration plate 1 without performing modifications on the support device. The vibration plate 1 has no separate drive of the exciter device 9. Instead of this, the exciter device 9 has a shaft 18 provided with a coupling 17, using which the exciter device

may be coupled to a drive of the snowcat and then driven thereby. A hydraulic hose 19 having coupling 20 is used to connect the exciter device 9 to the hydraulic system of the snowcat.

[0050] The variation of the cell structure 5 in size, shape, and cross-sectional dimensions may be recognized from the top view illustrated in Figure 2 of a part of the vibration plate illustrated in Figure 1. Thus, in the region below the exciter device 9, the cell long walls 6 and also the cell transverse walls are positioned more closely to one another. The edge of the baseplate 2 is also provided with more closely positioned cell transverse walls 7. The remaining regions of the cell structure 5 have cells which are formed from thinner cell long walls 6 and in which the support walls 8 and/or the ground plate 3, which are curved up at the front and rear, form the cell transverse walls 7.

[0051] The cell structure 5 is delimited in this case at the lateral edges of the vibration plate 1 by side walls 14, as may be seen in the section B-B shown in Figure 3. The profiled strip 13 is a trapezoidal profile for producing a furrowed piste surface in this embodiment. The vibration-insulated suspension elements 11 are positioned between the multipart exciter devices 9 and connected directly to the cell structure 5 in this exemplary embodiment.

[0052] In Figures 4 and 5, two details from two different cell structures 5 are shown, the cell shown in Figure 4 having a rectangular and perpendicular base and that in Figure 5 having a triangular base. The maximum lateral extension 22 of the base 23 enclosed by the cell walls 6 and 7 corresponds in Figure 4 to the external lateral interval of the diametrically opposing cell side walls 6 spaced farthest apart. In Figure 5, the maximum lateral extension 22 of the base 23 is the external lateral length 22 of the third and longest cell wall 21, which runs diagonally here. In the example of the cell shown in Figure 4, this means concretely, at a cell wall thickness of 3 mm and an open wall interval of the two diametrically opposite cell side walls 6 of 50 mm, that the maximum lateral extension 22 of the cell has a value of 56 mm. In a tubular cell having a circular base (not shown here), the maximum lateral extension thus corresponds to the internal diameter plus twice the wall thickness of the cell wall.